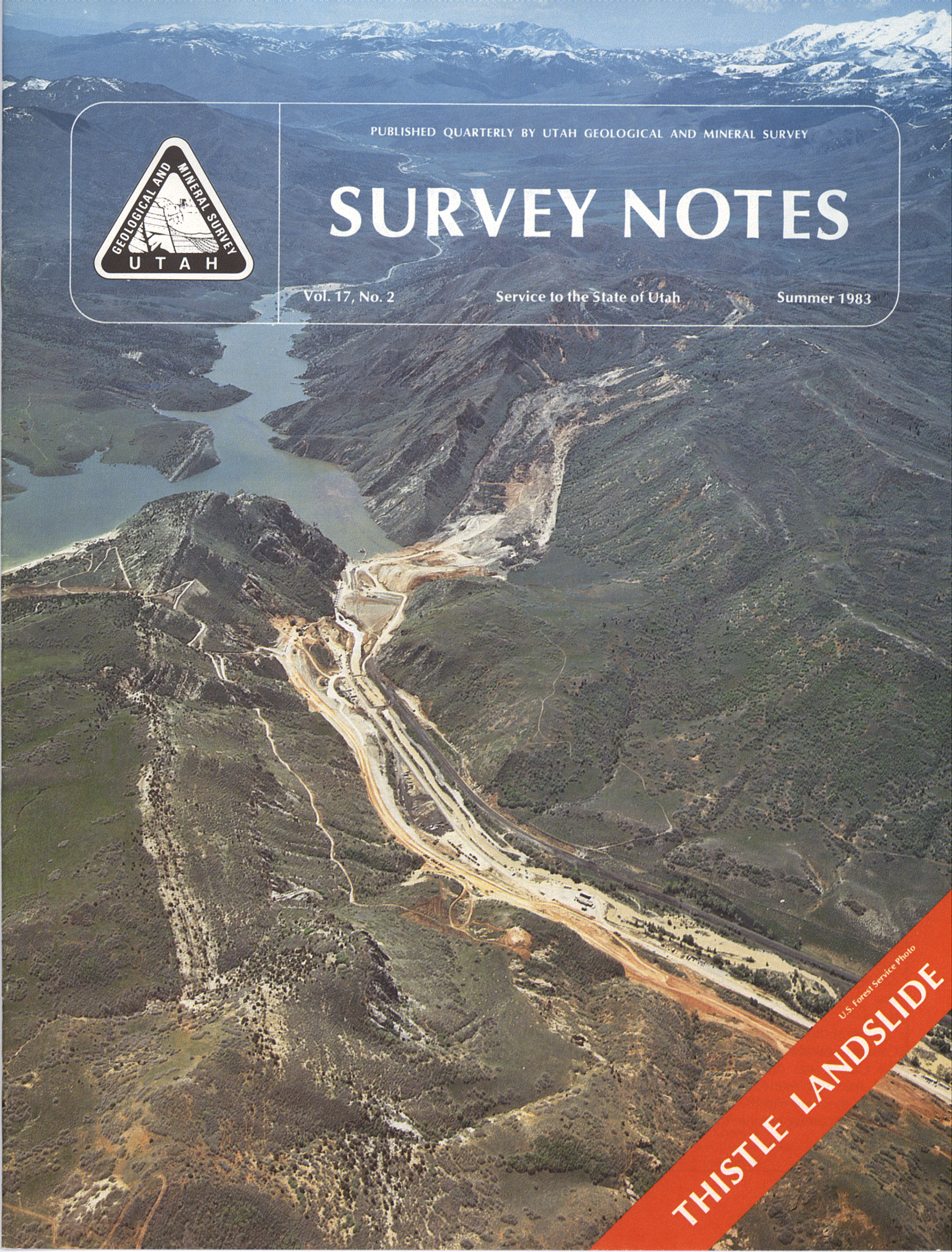
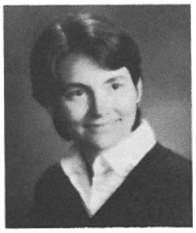
PUBLISHED QUARTERLY BY UTAH GEOLOGICAL AND MINERAL SURVEY

SURVEY NOTES

Vol. 17, No. 2 Service to the State of Utah Summer 1983



U.S. Forest Service Photo



From The Director's Desk

UGMS RESPONDS TO DISASTERS

This issue of *Survey Notes* is devoted to the UGMS role in responding to the Wasatch Front landslide disasters of the spring of 1983. UGMS efforts to document and understand the geologic impact of the wetter conditions of 1982-83 were undertaken in October 1982 as part of our concern about aggravated risk should there be an earthquake under such conditions. As the frequency of landslide events increased in early 1983, the variety (shapes, sizes, and causes) and number of unstable hillside conditions seemed unusual compared to "normal years." Two events in the early spring alerted us to the severity of potential geological hazards: the historically unprecedented rise of the Great Salt Lake, which ultimately rose 5 feet in nine months; and the reactivation, triggered by groundwater conditions which probably had not existed for hundreds of years, of part of an old massive landslide in Spanish Fork Canyon.

Even with these climatologic and geologic indicators, we were surprised by the events of late May and June. In less than three weeks entire sections of the State were plagued by a series of landslides and flooding and the UGMS role shifted from observation and documentation into a crisis mode of response.

The UGMS for years has had the lead responsibility in the state for the identification of the geologic hazards and especially identification of areas of risk. By "hazard" we mean the geologic condition itself. The "risk" takes into account the populations and structures that could be impacted. Risk and hazard combined result in "vulnerability." Before the Rudd Canyon mudflow on Memorial Day, the UGMS was documenting hazards and risks for many individual slides. With the increased frequency of events occurring in June, the UGMS efforts became almost exclusively directed to populated areas subject to mudflows and flooding caused by landslides, and to dams vulnerable to breaching from land failures. Fortunately, most of the events of 1983 occurred in areas of little risk. The UGMS called upon the USGS to assist in documenting these and evaluate the vulnerability. When such hazards actually endangered a town, its water supply, or other critical facilities, the UGMS and USGS worked as a team. Without help from the USGS and that of other Federal and State agencies, many hazards would not have been recognized or monitored.

During this crisis period, the UGMS responses included:

Thistle Slide — Immediately responded to Comprehensive Emergency Management's request for technical assistance and on-site inspections; made an initial evaluation of the magnitude of the hazard; provided a written evaluation of the stability of the "dam" and the determination that the unengineered structure posed an unacceptably high risk if the reservoir rose much higher than 100-120 feet; developed a map showing areas that could be flooded by failure; determined aerial photo and surveying and for monitoring the movements of the slide; documentated the lower east abutment geology before it was buried by the slide; requested bedrock mapping by the USGS and published the geologic map (UGMS Map 69); monitored the movements of the slide; provided engineering geology advice almost daily to the coordination team and to other state agencies; and contracted for an engineering geology examination of the toe of the slide.

Emergencies statewide — Examined hundreds of slides on site and flew over thousands of others; set up technical teams and trained hazard watchers (see page 12); drew inundation maps that were used by Comprehensive Emergency Management to estimate risk and propose response plans, and also used by local governments to plan for evacuations and sand bagging; inspected dozens of damsites (with Water Rights and U.S. Forest Service); advised city, county, and state officials.

Communication/coordination — Participated as part of the response team with the Departments of Public Safety, Transportation, Natural Resources, Agriculture and the National guard. UGMS worked directly with: FEMA (hazard/risk evaluation and advice for response); the Division of Water Rights (dam safety); USGS (hazard identification and documentation); the news media (information dissemination); U.S. Forest Service (evaluation of risk of hazards on National Forests); researchers (awareness of research needs and activities); and State agencies/Governor's Office/legislature (briefings).

Now that the immediate crisis period is past, it is time to evaluate our performance over the past months and the work we have done over the past decade in documenting geologic hazards and providing information to mitigate or prevent them. Now is the time to learn from this year's experience. The purpose of The Governor's Conference on Geologic Hazards (August 11-12) is to identify ways to implement what we have learned statewide. One of the things we have learned is the ability of county and city governments to respond to emergencies and to make effective use of information on geologic hazards if it is made available to them.

Genevieve Atwood

GEOLOGIC HAZARDS OF 1983

By BRUCE N. KALISER

1982 AND 1983 — WET YEARS

During the water year ending September 30, 1982, 25.19 inches of precipitation were measured at the Salt Lake City International Airport - 10 inches more than the thirty-year norm and the most for any year on record. New monthly records were set in October, July, and September 1982. The snow pack at Alta, Salt Lake County, for example, was 140 percent of normal. Such unusually high precipitation over an extended period of time was likely to have geologic consequences and the UGMS initiated a project in October 1982 to document the "wet year" effects. The anomalous weather has continued through the first three-quarters of the 1983 water year and has produced a series of geologic events that have had a major impact on Utah.

Problems began to emerge early in 1982. As a direct result of the heavy precipitation, the level of the unconfined ground water rose in many areas and were causing problems in the spring. On May 9, a 150,000 yds^3 rapid earth flow occurred in Salt Lake County causing over $2 million in damages. In June the Milk Creek Dam breach occurred and a number of small landslides occurred in Big Cottonwood Canyon. In July, a number of slope failures were examined in Uintah County. Landslides in Ogden and Layton in October 1982, were a warning of what was to follow as the 1982-83 water year continued the wet cycle.

As the spring of 1983 approached numerous earth slides were reported. Slides occurred in February in Utah and Davis Counties on the benchland terrain (below elevation 5,200 feet) and the UGMS was consulted by Provo City on the 1500 East slide. In March, the frequency of occurrence of benchland slides increased. The Hazards Section was consulted by Salt Lake County and the cities of North Salt Lake, Provo, and Orem. At the end of March, sliding of shallow colluvium was beginning immediately above 5,200 feet. On March 21 this writer conducted a helicopter reconnaissance of northern Utah counties when seven new slides were spotted. On the March 22, a news release was issued requesting the public to notify the UGMS of sliding events. Also developing in March were the U.S. Highway 40 earthfill slide north of Keetley, Wasatch County, which disrupted this major traffic artery.

In ensuing weeks reports were received on a considerable number of "sink holes," the result of ground surface collapse mostly related to human activities. Problems relating to high ground water were investigated by the UGMS in several areas of the State.

During April, a large number and variety of types of slope problems developed along the Jordan River and canals at the south end of Salt Lake County and the UGMS provided advice to the County Flood Control Department. During the week of April 10, the great Thistle landslide began to move severing a major railroad and highway, creating a 220 foot high dam, inundating a town and causing major repercussions to the economy of Utah.

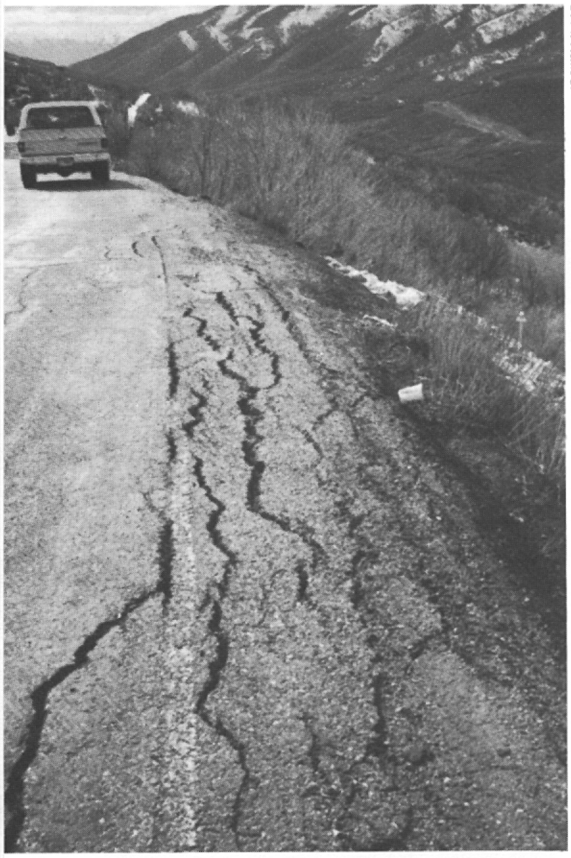
May brought emergency requests from Weber and Davis Counties and from the State Engineer's Office to investigate sliding of a dam abutment in Carbon County. Roads, including alternate routes to U.S. Highways 6, 50, 89 through Thistle, were effected by sliding. On May 9, an aerial reconnaissance was conducted of Davis and western Morgan Counties in which 28 new slides were observed, including non-damaging debris-slide-caused debris flows in Shepards and Baer Canyons. On Memorial Day, Farmington City was struck by a debris-slide-caused debris flow which destroyed 12 residences and damaged 37 others, 15 of them severely.


B. N. Kaliser

Ground surface collapse feature caused by underground erosion ("piping") of Lake Bonneville sands and silts on Interstate Freeway slope.

Throughout June, debris slides developed at increasingly higher elevations in most of the drainage areas of Salt Lake, Davis, Weber, and Box Elder Counties, many resulting in debris flows or debris floods. Also in June, landslides of many

IN THIS ISSUE



B. N. Kaliser

Tension cracks in asphalt surface of State Highway 65, Emigration Canyon, Salt Lake County, caused by insipient slope failure in Triassic shale derived residual soils and road fill. Total failure occurred two months later.

types, including hundreds of debris slides, developed over the Wasatch Plateau in Sanpete and Emery Counties. The towns of Fairview and Mayfield were threatened by canyon blockages caused by landslides and the former was evacuated on one occasion (see accompanying story on Twelvemile Canyon). Events related to the wet cycle continued into July with significant movement of the slopes bordering U.S. Highway 89 in Logan where a number of homes were damaged when the Logan Northern Canal was blocked by mud flows from higher on the slope.

Even if precipitation returns to normal or below, the geologic effects of the wet year cycle will continue for a minimum of several months. Many slopes are unstable and are vulnerable to thunderstorms or even a modest earthquake. If precipitation continues considerably above average the problems will become more intense in the future.

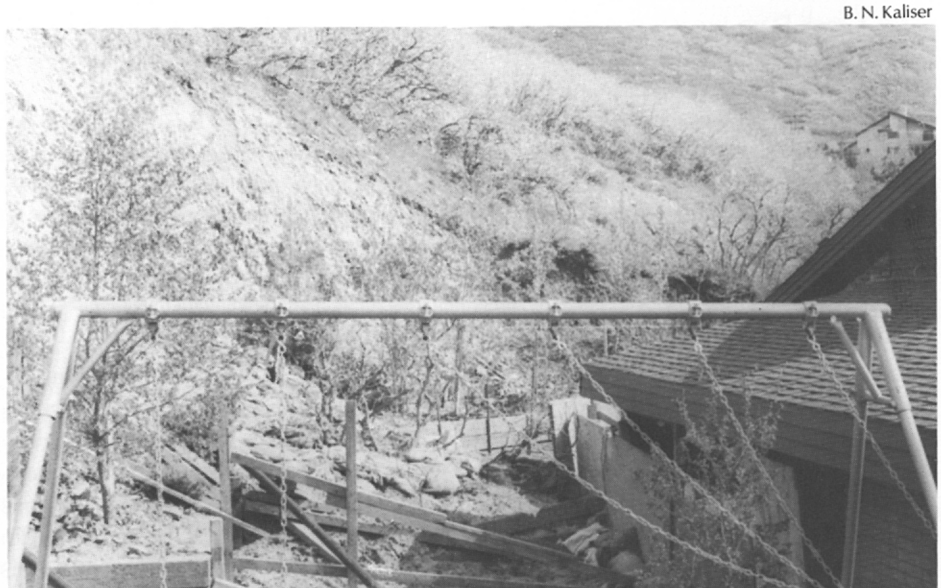
THISTLE LANDSLIDE: UTAH'S FIRST PRESIDENTIAL DISASTER DECLARATION

The Thistle landslide, which began to move on April 10, 1983, and continued through May, is by far the most costly geologic event in Utah's history. Direct costs will exceed $200 million and indirect costs are also very great. The landslide, which occurred below the confluence of Soldier Creek and Thistle Creek in Spanish Fork Canyon, and the lake it produced severed three major arteries: U.S. Highway 6 and 50, U.S. Highway 89 and the Denver and Rio Grande Western Railway. The unincorporated community of Thistle, Utah County, was entirely inundated, resulting in the loss of 15 homes, 10 businesses, and rail switching yards. The slide was responsible for the state's first national disaster declaration, which was made on April 30th. Economic losses include revenue losses to the railroad and trucking companies, greatly reduced employment in Carbon and Emery County coal mines, considerably increased mileage and travel time, reduced tourism, emergency response costs as well as direct losses. Many of the 10,000 residents of the city of Spanish Fork lie in the flood plain, 11 miles downstream from the slide at the mouth of the Spanish Fork Canyon. A rapid breach of the dam created by the landslide would flood at least 25 percent of that city as well as a wide area of the Utah County to the north and west.

Almost the entire earth mass that moved this year in Spanish Fork Canyon is part of a larger ancient landslide mass consisting of debris from the Cretaceous/Tertiary North Horn and Tertiary Flagstaff Formations. Larger fragments in the debris are limestones of the Flagstaff; the matrix is mostly clay derived from North Horn mudstone and claystone, and Flagstaff shales. Intermittent historical movement of the ancient Thistle landslide is known but is believed to have been confined to very small segments of the mass, mostly at the head and toe. Cumulative moisture during the 1981-82 and 1982-83 water years is believed to have created anomalously high groundwater pressure at the sole of the landslide mass and caused it to move.

During the first few days following the start of movement, the primary effort by man was to keep the channel of the Spanish Fork River open. This proved impossible as the toe of the slide heaved the valley floor upward as well as laterally toward the east. In a short time a massive assemblage of earthmoving machinery was concentrated at the

B. N. Kaliser



Slope failure of colluvium behind home along mountain front in Salt Lake City. Note projective measures with debris against house.

D. Eskelsen, Deseret News

Debris choked channel of Holbrook Canyon, Bountiful.

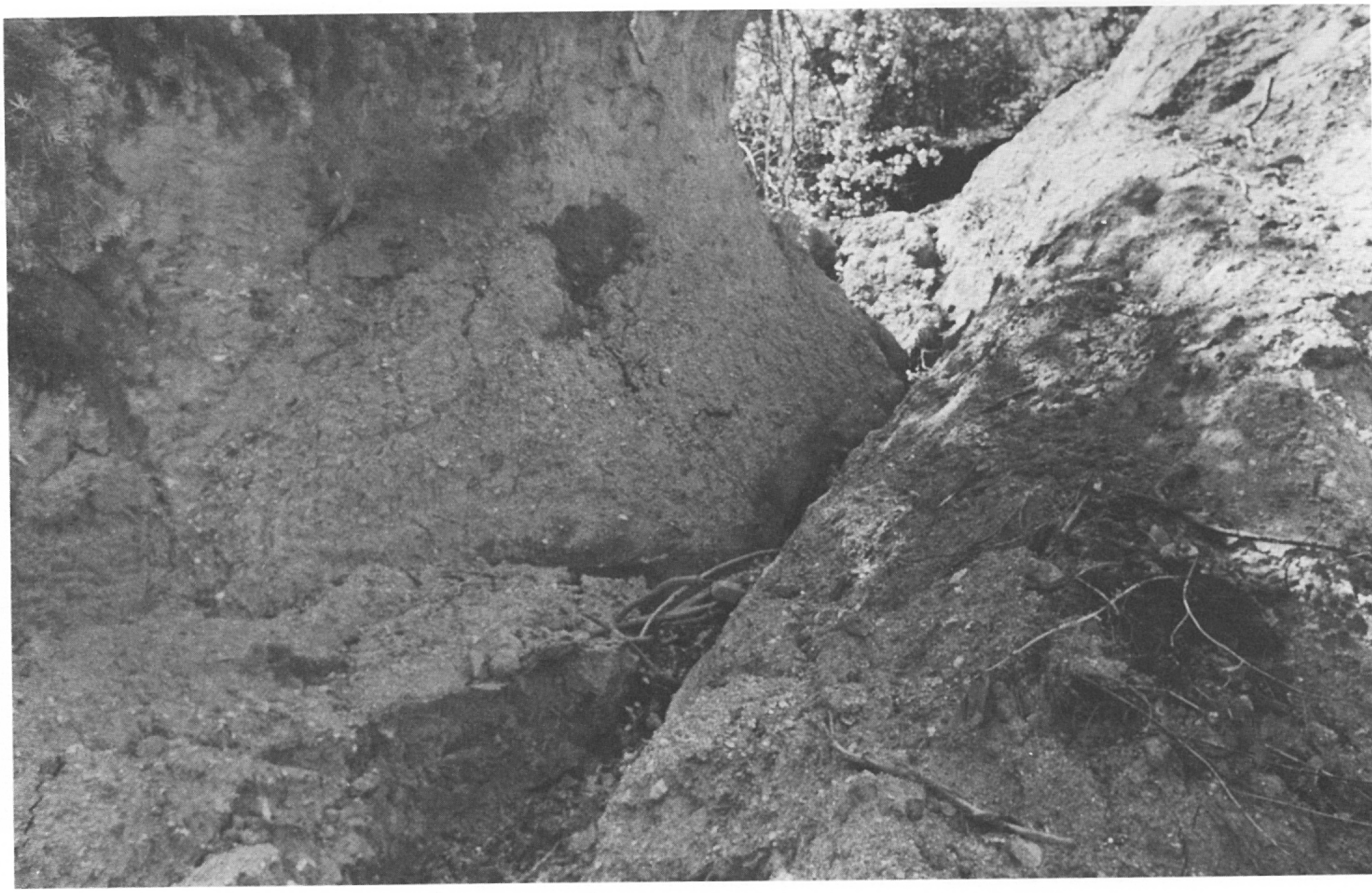
site in round-the-clock earth moving efforts commissioned by the Denver and Rio Grande Railroad. That first week saw the toe move an average of 5 feet horizontally and 3 feet vertically per hour at a non-uniform rate.

A near vertical wall of Lower Jurassic Navajo (Nugget) Sandstone on the east side of the river formed an east abutment to the landslide-dam. The Navajo Sandstone is a thick to massively bedded quartzose sandstone, moderate to moderately well cemented, mostly fine grained, with a total thickness of approximately 1,500 feet. Because of abundant small overhangs and cavities ("wind caves") and an extensive fracture system in the sandstone, considerable work would be required to prepare a satisfactory dam abutment.

The stability of the Thistle Dam looms as a major concern and one with considerable hazards implications. In addition to the question of the abutment, what of the foundation of the dam; has the entire section of canyon alluvial fill been carried into the slide? How extensive is the interconnecting fracture system created by the shear stresses and extension of the landslide flanks? To what depth are voids created by these stresses likely to exist and do they have hydraulic continuity? Does the permeable railroad embankment still possess continuity in the subsurface? Is upward seepage from subsoil rocks possible? Even after additional areal mapping of the landslide vicinity was completed by the U.S. Geological Survey, there are numbers of unanswered questions concerning the local geology. What is the potential for destabilization of the larger slide mass? What are prospects for shallow or for deep seated movements? Is there an active fault in the canyon? Extensive colluvial cover masks much of what one would like to know but, nevertheless, detailed work would doubtless shed additional light on these questions. Based on a recommendation by the UGMS piezometers are being installed in three test holes. Continued monitoring of UGMS's 40 survey targets on the slide and in the slide vicinity may prove helpful.

Geological engineering has also played a role in relocation of the railroad and highway. First, an overflow tunnel at elevation 5,187 feet was constructed to control the level of Thistle Lake. A new railroad tunnel and grade is in operation, a low elevation (5,005 feet) drainage tunnel is under construction by the State and a new highway alignment for U.S. Highway 6 and 50 over Billie's Mountain is being prepared. The railroad tunnel is in the Navajo and Twin Creek Formations and the others are entirely in the Navajo Sandstone. Outside of the tunnels difficult terrain had to be crossed by both the highway and railroad.

The saga of the Thistle landslide is far from over. Already, certain parties want to make Thistle Lake a permanent reservoir. The UGMS and the Division of


D. Eskelsen, Deseret News

Canyon channel scour in unconsolidated sediments of Barton Creek, Bountiful.

Water Rights have advised the Governor that the Thistle landslide cannot be considered a safe dam and that the lake must be drained.

A significant geologic event occurred in Spanish Fork Canyon in a remarkably short time span. The time required to acquire the geologic and geotechnical facts necessary for permanent solutions will be much longer than the duration of the event.

WASATCH FRONT DEBRIS FLOWS

An integral part of the well publicized landslides and floods that affected the Wasatch Front in 1983 included the slide-caused debris flows. Extensive property losses resulted in Davis County in particular though debris flows and debris floods were documented in abundance elsewhere along the Wasatch Front and the Wasatch Plateau. Debris flows are one form of geologic mass wasting phenomena with a high proportion of solid material mobilized by a realtively small volume of water. If more than half the solid material is silt and clay fraction then such flows are called mud flows. The wet end of the continuum, debris floods, is represented by running water carrying a sediment load with a smaller proportion of solid material transported by a far greater volume of water.

Damaging debris flows have been documented along the Wasatch Front for over a century. Good documentation for Davis County exists for several years in the 1920s, 30s, and 40s, and even for earlier decades when debris flows and floods damaged or destroyed homes, water systems, and roads. These earlier floods and debris flows followed heavy summer rainstorms and were the likely result of overgrazing and other poor watershed management practices.

This year's events in Davis County were clearly caused by shallow landslides on steep mountainous slopes. Occurrences of these debris slides were at increasingly higher elevations as the snowline rapidly receeded upcanyon. A period of cumulative high groundwater level from the prior 18 months of excess precipitation was a major contributary element as well as the above average snowpack. Snow melt in 1983 was a whole month later and much more voluminous than usual. As an example, at the upper Farmington Canyon snow course (8,000 feet elevation) there were 102 inches of snow on May 27 with a water content of 51.8 inches, 305 percent above that of 1982 and 418 percent above normal for that date. The Farmington weather observation station recorded 4.46 inches of precipitation in May this year, twice the May norm, and average temperatures for May of 67°F, 8°F above normal. For the nine days preceeding the onset of debris flow activity

D.F. Colvin

Debris flood damage at top of residential subdivision, mouth of Coldwater Canyon, North Ogden City.

in Rudd Canyon (above Farmington City, the county seat) the average temperature was 84°F, considerably above normal.

Three Davis County communities were hit the hardest by debris flows and debris floods: Farmington, Centerville, and Bountiful. In addition, North Ogden in Weber County and Willard in Box Elder County were affected. Debris flows and debris floods destroyed 13 residences, severely damaged 40 residences, and caused considerable damage to 350 others in Davis County. Damage to lifelines (water, sewer, streets, utilities) was considerable. Local, state, and federal governmental entities responded to the emergency as well as local industries, community and church groups.

Farmington City had experienced a series of debris flow surges from the "half canyon" of Rudd Creek commencing on May 30 (see "Sights on Sites" column, page 10). The first surge demolished 5 homes and severely damaged 13 others situated on the alluvial fan west of the canyon mouth. Surges occurred thereafter at a frequency of about every 2.5 hours, decreasing in frequency to about five hours half a day later (May 31). The debris flows were true mud slurries consisting of silt, sand, gravel, boulders, vegetative debris and perhaps as much as 2 percent clay.

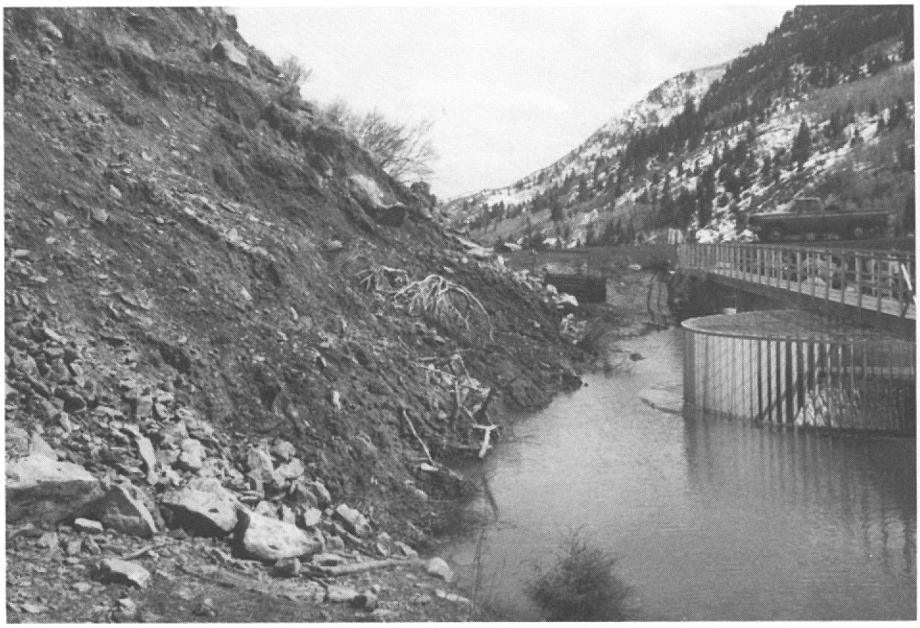
The viscosity of individual surges varied considerably over time intervals of as short as a few minutes. It is evident from observers' logs that short duration blockages of the canyon occurred periodically from debris slides, followed by breaches resulting in debris flow fronts or surges. Many of these surges were of viscous slurry that reached the alluvial fan as debris flows with rather well defined margins; others became sufficiently diluted by the high creek discharge (near flood peak) to produce debris floods across the fan.

The majority of the debris slides that led to debris flows in the Wasatch Front canyons were shallow failures of colluvium on steep mountain slopes. Bedrock was normally at depths of 10 to 20 feet on these slopes and the volume, therefore, was small except where the areal extent was large. Rudd Creek was an important exception. Here the initial debris flow resulted from the mobilization of part of a wedge of unconsolidated material, likely an ancient landslide mass, situated ("perched") in the main drainage of Rudd Canyon at about elevation 6,925 feet. A large bench with an average slope of less than 10 percent exists on this partially failed soil mass in Rudd Canyon. This situation, with relatively permeable granular soils derived from the metamorphic rocks of the Farmington Canyon complex, represented ideal conditions for infiltration of snowmelt waters into the perched soil mass and the development of a high piezometric level (i.e., ground water pressure) in the debris from both direct snow melt and runoff from the catchment area above.

The gradient of Rudd Creek is quite steep, among the steepest of the Davis County frontal canyons. Below the main slide down to the Bonneville terrace (elevation 5,200 feet) the average gradient is 41 percent. Above the main slide, it is 35 percent, and it is considerably less (24 percent) below elevation 5,200 feet to the apex of the alluvial fan. The canyon was without major obstructions or bends and the debris flows and floods scoured much of the channel to bedrock.

These are not the first debris flows from Rudd Canyon. Prehistoric debris flow deposits, are exposed at the apex of the Rudd Canyon fan and older debris flow deposits at a somewhat higher elevation have been faulted along a major active fault trace where it transects the mouth of Rudd Canyon. Our understanding of the age of these deposits is insufficient to permit estimates of recurrence intervals for these geologic hazards, but it appears certain they have occurred several times in the last few thousand years.

One major problem facing the Wasatch Front and particularly Davis County communities after the disastrous events of May and June is how to assess the degree of hazard that remains from destabilized slopes in the watersheds above their communities. In the immediate vicinity of already failed slopes there are partially detached earth masses and internally disturbed "dilated" soils. Movement of these


B. N. Kaliser

Disturbed slope on left is toe of landslide which comprises left abutment to dam and reservoir slope immediately upstream.

masses could be triggered by an earthquake or by increase in the piezometric head of ground water, by severe thunderstorms or snow melt in subsequent spring seasons. Flash floods may occur during the month from May through September in this area, so the hazardous period is not yet over. Consideration must be given now to remedial measures that can be taken in the watersheds, on the slopes, in the channels, and on the alluvial fans beyond the canyon mouths — solutions that incorporate both engineering and non-engineering methods. Among these possible measures are debris basins, channel modification, removal of obstructions, public acquisition of areas defined as high risk zones, watershed treatments, and enactment of zoning ordinances.

HAZARDS TO AND FROM WATER IMPOUNDMENTS

Water impoundments, even relatively small ones, can cause considerable damage should they fail. The geologic hazards of the spring of 1983 endangered some existing impoundments and created some additional ones. One dam failed. Several endangered structures were breached or their reservoirs lowered. Many threatened dams were closely monitored. Several landslides caused temporary blockage or threatened blockage of drainages in Davis, Salt Lake, Utah, Sanpete, Emery and Box Elder counties.

The failure of the DMAD dam near Delta in Millard County damaged bridges, roads, and flooded residences and acres of farmland when it released approximately 16,000 acre feet of water. Thistle landslide in Spanish Fork Canyon (see page 4) created a lake which in early June was over 200 feet deep and 3-1/2 miles long. It has been the most expensive single geologic event in the nation this year. In several other canyons landslides blocked channels but the streams re-established their drainage rapidly and less serious damage occurred. As one example, a chasm exists today in the lower section of Little Clear Creek, northeast of Indianola in southern Utah County, where a sequence of landslides crossed the drainage in late May or June but the stream later broke through. Severe siltation occurred downstream but property loss was less than might have occurred had a greater volume of water built up behind any one of the landslides.

Twelvemile Canyon in Sanpete County, east of Mayfield, had amongst its numerous slides two of particular concern because they threatened to cut off the drainage, and one of the landslides appeared to threaten the enbankment and/or reservoir of a small dam which happened to be located just above an internal scarp of the landslide. Both large and complex landslides are capable of blocking the canyon. These

(see page 14)


B. N. Kaliser

Typical circular (failure plane) landslide on Provo City's high east bench, in ancient landslide terrain. Note toe crossing 1500 East Street and resting on front yard (left, foreground).

Looking Backward

By Wm. LEE STOKES

Edmund A. Spieker's Contribution to Utah Geology

Edmund A. Spieker died in 1978 at the age of 83 after a long and productive professional life, most of which was spent in central Utah. I did not get to know him well, but we did share an experience in Utah geology. In 1948, I conducted the 3rd annual field excursion of the Utah Geological Society into the Utah-Colorado salt anticline region. Having just completed and published a map of Gypsum Valley, I was full of enthusiasm for salt-generated structures. The following year, 1949, Spieker conducted the 4th annual field excursion of the Utah Geological Society into central Utah. At almost every stop I could see duplicates or analogies of conditions I knew of in the salt anticlines. My instincts were to publish, but I never had the time to do the few days field work that would have justified it.

Looking Backward
Third article in a continuing series

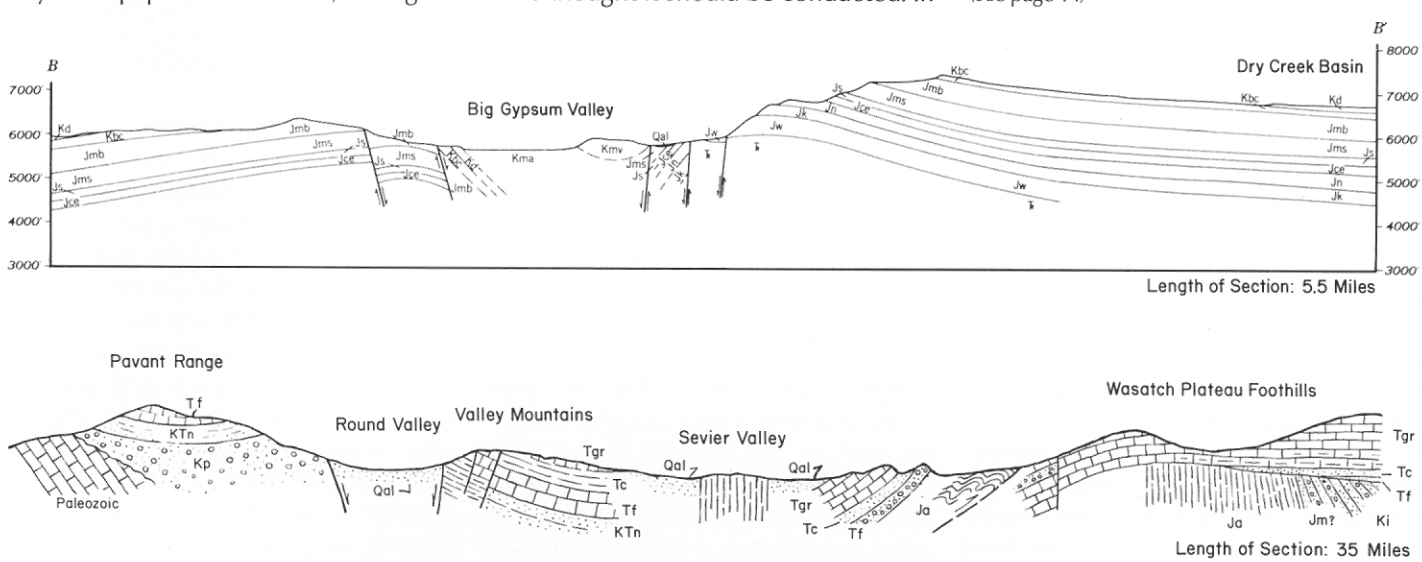
However, I did present a short paper at the 1952 AAPG meeting in Salt Lake City. The paper was entitled, "Salt-generated structures of the Colorado Plateau and possible analogies." I didn't attack Spieker's work, I merely dwelt on the similarities of his area and mine. It came to me by the grapevine that his comment was, "Stokes should have talked to me before he expressed himself." Perhaps he was right, that is past history.

I do want to say something more about his work philosophy. He wrote this:

> "For many years I had little faith in college field training courses. Experience in USGS field parties with assistants who were alumni of such courses convinced me they had never been caused to do any real field work, or had been instructed by men who knew nothing about it. I used to say they would have been better off if they had never had such a course; so during the first 20 years or so of my tenure in the Department of Geology, I had nothing to do with the field course operated by the Department."

To make a long story short, he had a change of heart and in 1947 began to conduct the field course in central Utah as he thought it should be conducted. In subsequent years, Spieker's students completed 12 doctoral dissertations and 31 master's theses. by 1956, Ohio State personnel had completed the geologic mapping of all Sanpete County and large parts of surrounding counties. Spieker himself contributed 14 papers on the region. I do not believe it is unfair to surmise that the concept of diapirism had nothing to do with how he mapped the geology. The surface geology can be accurately shown under a number of theories. The peculiarities that we now attribute to diapirism were described in such statements as: "Most of Sanpete Valley is underlain by the folded complex produced in the early Laramide and later compressional movements" and "the cheese-like shale rose under pressure" and "the site of Sevier Valley was occupied during the Late Cretaceous and early Tertiary by ranges of Arapien hills much like those of today."

Terms such as diapirism, intrusive movements, dissolution, and collapse are not found in Spieker's descriptions. Nevertheless, his contributions were profound. I recently asked a coal geologist, well versed in the Wasatch Plateau fields, how he evaluated Spieker's work. He both praised and complimented the accuracy and thoroughness of U.S. Geological Survey Bulletin 819. This is still a bible to those who now evaluate and mine the multimillion-ton reserves of this field, the value of which (see page 14)



Cross sections of Gypsum Valley, Colorado (above) and Sevier Valley, Utah (below). The upper section by Stokes and the lower one by Spieker are shown together to illustrate conditions that are interpreted as being due to similar histories of growth and collapse of central diapiric masses.

THE DAVIS COUNTY EXPERIENCE

By BRUCE N. KALISER

When the flooding and debris flows struck Davis County in late May and early June, the primary responsibility for response to the emergency fell upon the County and its incorporated cities. However, they needed technical assistance. What are we to expect? Shall we evacuate additional city blocks; if so, in which direction? Where, in town, is the debris likely to be thickest? Can we expect worse - when? What exactly have we been hit with? These questions and more confronted me as I arrived in Farmington at 11 p.m. on May 30 to investigate the debris flow that a few hours before had moved down Rudd Canyon and struck the city. I had just returned to Salt Lake City from a field trip and had very little knowledge of what had transpired during the preceding hours. After a short briefing by Farmington City and Davis County officials, I ventured into the field with a strong hand light. Heading for the topographic bench above the canyon mouth of Rudd Creek I was intercepted by two frightened county personnel. Only moments earlier both had heard the deafening roar and felt the trembling earth from another surge of mud and debris passing by them in the channel incised in Lake Bonneville sediments above the canyon mouth at about elevation 4,700 feet. Though literally in the dark, I was able to discern the runup of the first debris flow surges on and over the confines of the channel walls and considerable channel scour creating clean, vertical walls. By observation and questioning of people, I established the major characteristics of the debris flow and determined the scope of the problem facing Farmington.

Because there was no historical record of debris flows or floods in Rudd Canyon, there was no past experience to draw upon. The U.S. Army Corps of Engineers flood study for Davis County (June 1974) proved useless, as Rudd Canyon was not even declared susceptible to flooding. Technical help was urgently needed to develop courses of immediate action.

Because the time, size, or velocity of future surges could not be predicted, some warming system based on direct observation was required. Extreme winds prevailed throughout that night, masking sounds thereby requiring reliance upon visual observation. My first recommendation was to acquire powerful spotlights to illumintate the channel at the upper bench elevation. The Weber Basin Aqueduct observation point at an elevation of 4,700 feet above the canyon mouth, would permit a couple of minutes or so of warning time before a flow reached a residential neighborhood of Farmington situated at the apex of the alluvial fan.

Sights on Public Facility Sites
Eleventh article in a continuing series

Arrangements were made about 2 a.m. for a party to ascend the mountain on foot and at dawn five of us headed east on the north side of the canyon to view the awesome sight of destruction below and canyon section scoured to bedrock above. At about elevation 5,500 feet the trail was severed and the canyon wall was too steep, too talus covered, and too thickly vegetated for us to climb and observe upstream. Not knowing the distance to the origin of the problem, we decided to abandon the effort. We returned to the upper Bonneville bench, elevation 5,200 feet, where a news media helicopter (KSL-TV 5) recognized me and landed to pick me up. By now it was mid-morning and the fierce wind had subsided. These first aerial observations from the helicopter enabled me to clearly define the source of the problem, a mass of unconsolidated earth or soil perched in the steep canyon floor with its westward facing free face truncated by a debris slide. The failed material had brought down trees, and water was issuing, in prodigous amounts, from numerous springs in the new scarp and at several places on the adjacent north canyon wall. The geometry of the soil mass was such that the development of additional detachment blocks was possible, even probable. Ground cracking parallel to the crown was already in evidence. Another, much smaller debris slide was observed on the north canyon wall. This slide sent a debris flow down the main Rudd drainage onto the surface of the soil wedge which had the major slide at its westward edge. Destablizing factors in the canyon included the extremely high ground water levels, the scarp-caused oversteepening of the perched soil wedge in midcanyon, the oversteepening of the scoured channel walls, the thick and rapidly melting snow cover at the slide elevation, and the abundance of trees which would aggravate the transit of any detached mass down canyon.

A verbal report was immediately made at the Emergency Operations Center located in the basement of the Davis County Library after which I proceeded to organize a technical team. The team included the County Engineer, representatives of the U.S. Army Corps of Engineers, Utah Department of Transportation, and the U.S. Forest Service. The corps of the technical team consisted of six people: geologist, civil engineer, soil scientist, hydrologist, and two geotechnical engineers. Meetings were set for morning and afternoon and an aerial monitoring plan was developed. Initial aerial reconnaissance was made with media and Utah National Guard helicopters but a U.S.Forest Service helicopter was soon made available for the twice-a-day reconnaissance missions. A large room was used solely by committee members with 1″=200′ scale maps hung on all the walls. These maps, provided by the County Planning Department, became the base maps for the rapid preparation by the committee and county engineering and planning staff of potential inundation or damage area maps. As quickly as these maps could be completed, they were dispatched to the respective city mayors. Priority of preparation was assigned based upon the canyon hazard ratings.

At technical committee meetings,


D. Eskelsen, Deseret News

Tree damage indicating maximum debris flow surge height in Barton Creek, Bountiful.

tasks were assigned, progress was reported upon, problems identified, and canyon hazard ratings determined for all of the Davis County drainages, based on the aerial reconnaissance missions. Following these meetings, I would report to a group of local elected officials as to what was being accomplished and the new ratings for the day. The purpose of the technical committee was to anticipate questions and to provide answers to the emergency response team (County Emergency Services Office and Sheriff) and elected officials so that the best expertise available was being used in the daily decision-making process. The technical committee had a major role in seeing that the public was being protected and informed, unnecessary expenditures were avoided, timely decisions were made, and emergency response facilitated. Initially, I, as chairman of the technical committee, was asked to address the public and the media on technical matters. Later, two county information officers were designated who included technical content in their communications to the media.

A blackboard listing was kept current with canyon ratings and the time for the next meeting so that it was visible from the room entrance for any official wanting this information. The Davis County Technical Committee functioned effectively for a period of three weeks. Its final action was the release, on June 21, of a canyon rating list which apprised local government of the relative degree of hazard existent in the canyons at that time. In addition, local officials were warned that high intensity summer storms are capable of creating debris flows now that unstable slopes exist in these canyons. The Davis County Technical Committee may serve as a model for dealing with similar crisis situations in the future.

In addition to the technical committee's efforts, round-the-clock monitoring was needed in several of the canyons in Davis County. Rudd Creek Canyon was the first to be monitored on a 24-hour basis. A tent was set up on the south side of the canyon with a notebook or observer's logbook which was to remain in the tent at all times. The observers were assigned a radio code number and asked to check in with the Emergency Operations Center each hour. They were asked also to remain on site until relieved by the next crew and to initial their notations in the logbook in the event there were later questions. At an orientation session, the debris-flow phenomenon that was occurring was explained to observers. They were told to be alert for any evidence of earth movement — that in addition to visual recognition, events might be heard, felt, or even smelled; indeed, some observers even reported that they could taste the soil in the air. The importance of weather observations, particularly initiation and cessation precipitation periods and wind were also emphasized. Observers were asked to describe any changes in canyon discharge, including color, shade, level, transported debris, volume fluctuations, etc., and to note exact time of all observations in the log. A gage was installed across Rudd Creek at noon on June 1 so that observers would have a basis for noting fluctuations of the

(see page 16)

Remote Sensing of Utah's "WET-PERIOD" PHENOMENA

By WILLIAM F. CASE

The Hazards Section of UGMS is in the process of indexing and compiling photographs and images of landslides and other geologic hazards related to the last two wet years. A variety of remote sensing devices including satellite (LANDSAT), conventional aerial cameras, panoramic aerial cameras, hand-held cameras, and video cameras were used to document geologic events. Many agencies including state, federal, and municipal as well as commercial concerns and private individuals have contributed to the UGMS effort to determine the extent and nature of the recent 'wet-period' damage.

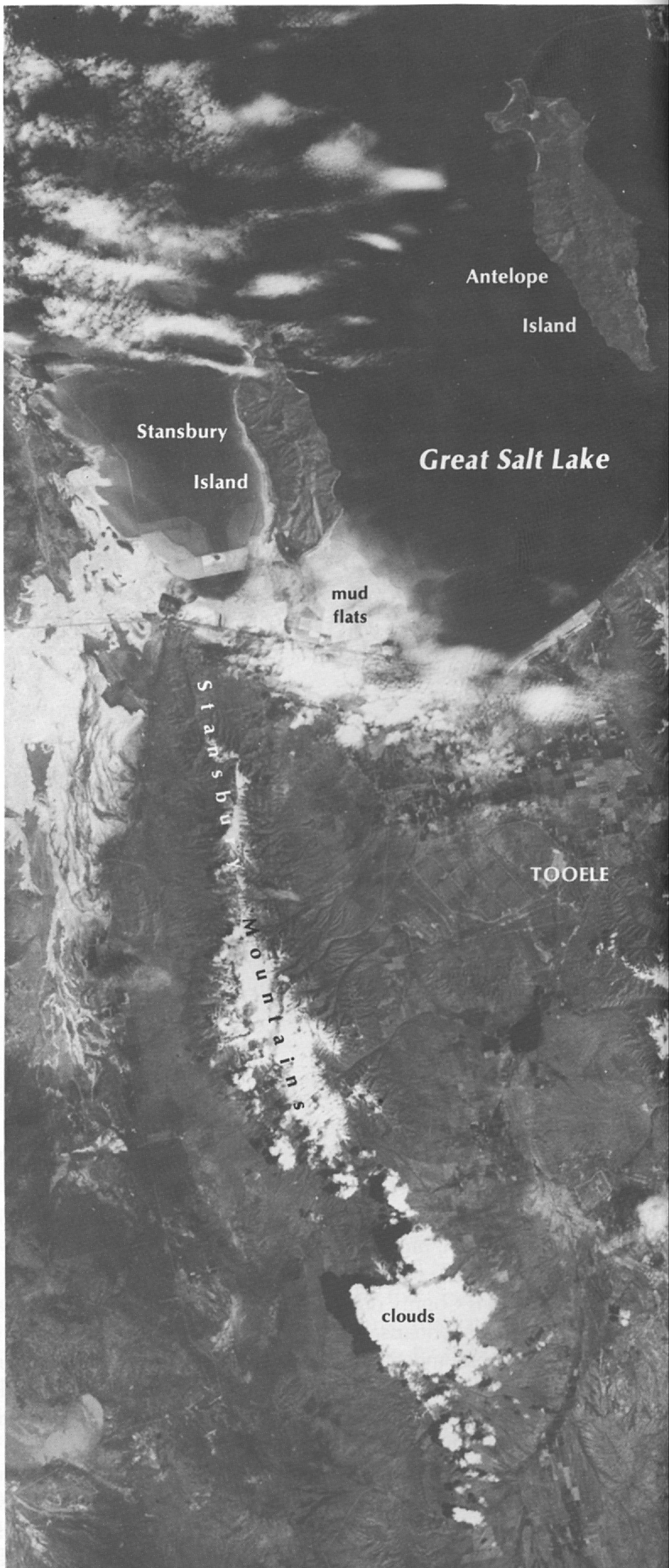
LANDSAT images of the Wasatch Front on 30 May 1983 show the unusually extensive snow cover at relatively low elevations that existed this year. The advantages of LANDSAT images include uniform coverage of large areas showing in addition to snow pack, large scale flooding of streams and the extention of Great Salt Lake, Utah Lake, and Lake Thistle. Large landslides, such as the Thistle landslide, are apparent on the LANDSAT images.

More detail but less overall areal coverage of hazards is possible from photographs taken nearer the earth's surface. High-altitude, vertical aerial color infrared photographs of Thistle landslide and the Wasatch Front area were taken by NASA using a U-2 type aircraft. A request has been made to NASA to obtain coverage of all the areas of Utah where major landslides occurred this spring. The Intermountain Region of the U.S. Forest Service has taken low-altitude, natural color, vertical aerial photographs of landslides and geologic hazards in the Uinta, Wasatch, and Manti-La Sal National Forests.

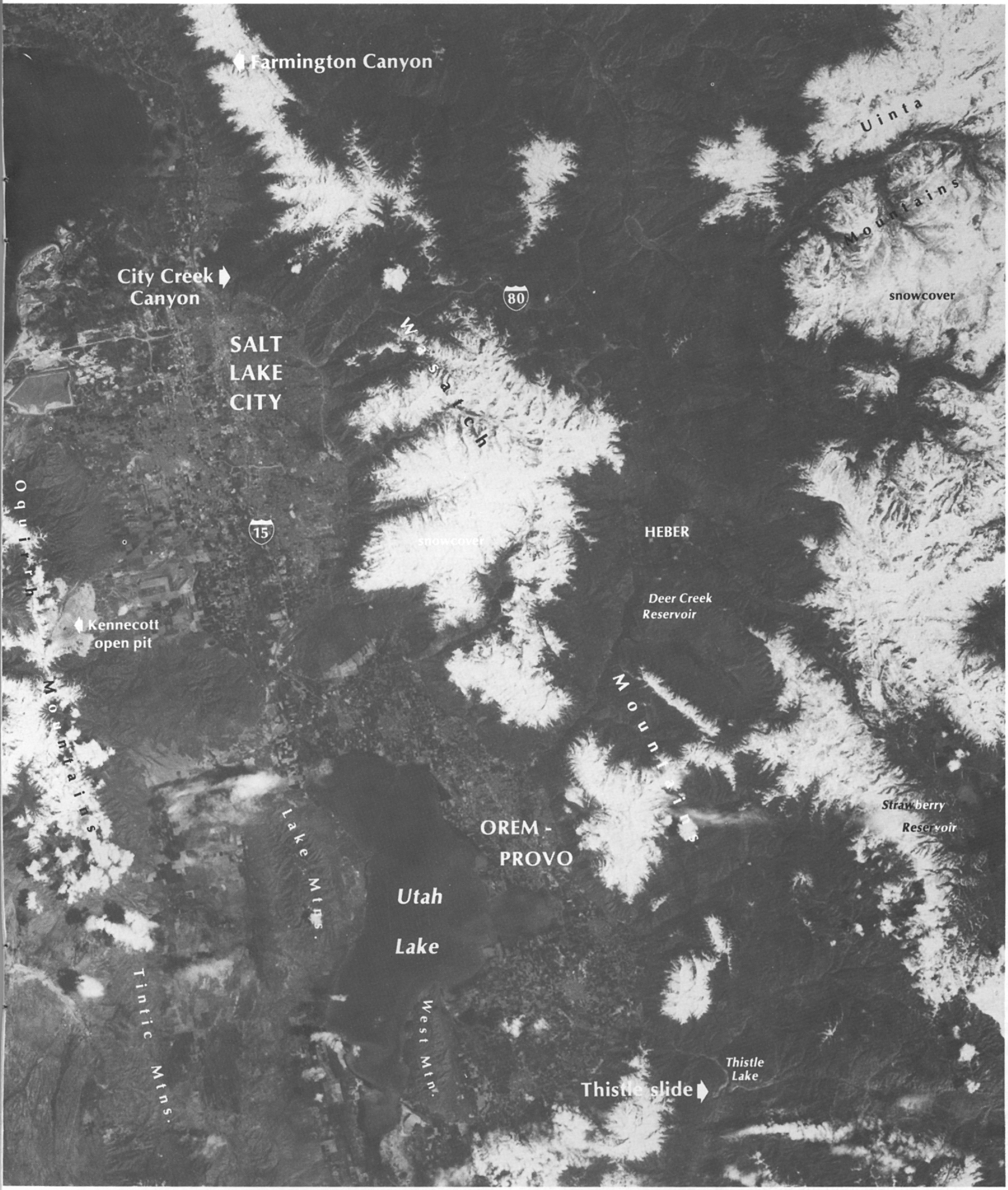
A vertical, panoramic aerial camera was flown at low-altitude over the Wasatch Front by the Idaho National Guard as requested by the Division of Comprehensive Emergency Management. The UGMS placed circular targets on the Thistle landslide and had a commercial firm and the Department of Public Safety take natural color, vertical aerial photographs to determine movement. The Davis County Technical Committee established at the onset of emergencies in Davis County contracted a commercial firm to take black and white, vertical aerial photographs at a low altitude over the fans of Barton, Stone, and Rudd Creeks in Davis County.

The ENVIROPOD, on loan to the Center for Remote Sensing Cartography from the Environmental Protection Agency, was used to take low-altitude, panoramic photographs of hazards in natural color and color infrared. The Utah Department of Public Safety has provided use of Utah Highway Patrol aircraft and pilots to UGMS to fly the ENVIROPOD cameras (vertical and oblique) over several areas affected by

(see page 16)



Color Composite Image, NOAA LANDSAT



Portion of central Wasatch Front illustrating extraordinary extent of snow cover on May 30, 1983.

USGS HELPS OUT

The applied geology staff of the UGMS responds to numerous geologic emergencies, but the spring of 1983 produced an unprecedented number of slope stability and high ground water problems that required immediate attention. The staff responded admirably to the emergency but needed help. When help was needed, the UGMS turned to the U.S. Geological Survey and the Federal survey responded.

Irving Witkind, a USGS geologist in Denver, had been preparing a regional geologic map of a large area of central Utah including the Thistle slide. When it became apparent the highway and railroad would have to be relocated around the slide, Witkind flew to Utah to brief State and consulting geologists working on problems relating to the slide. Within a few days he and W. R. Page started preparations for a 1:24,000 scale map from the Thistle area and within two months of the start of the field work, the map had been completed, reviewed, approved by the USGS, and was published by the UGMS as "Geologic map of the Thistle area, Utah County, Utah" (UGMS Map 69). The cartography and final editing for the two-color map was performed by UGMS editorial staff.

With hundreds of landslides and mudflows throughout much of Utah, the UGMS staff, although experienced with these phenomena, needed assistance to investigate and monitor all the critical events that threatened life and property. The USGS assigned Robert Fleming, who had previously worked on Utah landslides, to work directly with the UGMS staff. In addition, several other USGS landslide and mudflow experts performed specific tasks suggested by the UGMS

This has been an outstanding example of cooperation between a state survey and the Federal survey. Utah's problems of coping with geologic emergencies will be considerably eased if we can continue to rely on help from the USGS. ■

("Geologic Hazards" cont'd. from page 8)

slides are directly opposite one another with opposing directions of movement. The landslide on the north is very thick (on the order of 300 feet) and affects bedrock as well as surficial materials. After two days of monitoring the landslide on the north side, named the Twin Lake landslide, it was decided by the three geologists on site that the landslide represented a potential threat to the Twin Lake Reservoir and its 18-foot high, 376-foot long, 1930 vintage earth dam constructed on USFS land by a local irrigation district. In the process of rejuvenation of the ancient landslide ground cracks formed in what appeared to be quantum jumps upslope along old internal scarps. The State Engineer's Office was notified of the threat and immediate measures were taken to have the dam breached.

The UGMS and USGS geologists monitoring the slide recommended the reservoir be drained down Birch creek, an intermittent stream which bordered the slide on the west. The spillway crest was lowered with the bulldozer in 2-inch and then 6-inch increments. Fortunately, the clayey nature of the North Horn Formation-derived soil of the dam is highly resistant to erosion and each successive cut held until the reservoir level was lowered 3-1/2 feet and over half the reservoir's capacity was spilled.

While the discharge remains high down Twelvemile Canyon, erosion will continue to prevent closure of the channel by the two landslides. However, if the slides continue to move and if the stream loses its capacity to maintain its channel, the configuration of the channel (in an "S" curve) is such that it may ultimately be blocked, with a low gradient stream section upcanyon. This could result in a fair-sized reservoir. Should impoundment and later rapid breach occur, a portion of Mayfield would be inundated. Therefore, these landslides are being monitored.

Another single large landslide west of Joes Valley Reservoir in Straight Canyon (Seely Creek) also is being closely monitored. A mile-long slide has been re-activated and could block Seely Creek and form a significant impoundment upstream.

The UGMS presently is working with Sanpete County on the Twin Lake slide situation and with Emery County on the Seely Creek problem. Inundation maps have been prepared for each landslide breach potential and forwarded to the local authorities. County and local officials are prepared to take immediate action if necessary. ■

("Looking Backward" cont'd. from page 9)

Spieker could not have dreamed of in the 1920s.

In the 1950s, I invited Dr. Spieker to address our geology club at the University of Utah. His topic was, "You find what you are looking for." We might say that he did find what he was looking for in some ways, but in one area he did not and as a consequence one of his papers became a world classic. He started his USGS career under the time-honored philosophy that geologic history is punctuated by well-marked breaks that neatly divide the periods and eras of the classical time scale. Any field geologist worth his salt was expected to find and map these unconformities and not to come in until they were mapped. Spieker's area includes both Mesozoic and Cenozoic rocks, but try as he might he found no break between them. Although he found evidence of 14 episodes of crustal movement, not one is as the proper horizon. His great paper, "Late Mesozoic and Early Cenozoic history of central Utah," published as USGS Professional Paper 205-D in 1946, probably did more than any other work to demolish the time-honored dogma that diastrophism is the only correct basis for dividing the geologic column and time scale. It was hard going for Spieker — I happened to see his manuscript. It was criss-crossed with pencil lines of more colors and interlined with more suggested changes than any manuscript I have seen before or since. ■

UGMS STAFF CHANGES

On August 8, **Dianne Nielson** joined the UGMS as senior geologist for the Economic Geology Program. The UGMS Economic Geology Program consists of three sections: Petroleum (including oil shale and tar sands); Energy (coal, uranium, and geothermal); and Minerals (metallics, industrial and saline resources). Over half of the investigations undertaken by UGMS geologists are included in that program.

Dianne received her bachelor's degree from Beloit College in 1970, her master's from Dartmouth in 1972, and her doctorate from Dartmouth in 1974. Her work experience includes three years with Great Lakes Exploration Company (a subsidiary of Bear Creek Mining Company), four years with the Anaconda Company, and five years as a consulting geologist conducting property evaluations, exploration and development for uranium, base metals, and precious metals in the western U.S. as well as oil and gas exploration and production in Utah, Wyoming, and Colorado. Many of us know her from her service as president of the UGA from 1981-82.

Charles (Jack) Oviatt, Mary Siders, and **Grant Willis** recently joined the staff of the UGMS. They have the enviable job of systematically mapping the state geologically.

Jack Oviatt received his B.S. degree in 1973 and his M.S. degree in 1977, both in geology, from the University of Wyoming. His master's thesis dealt with glacial geology in the Medicine Bow Mountains of Wyoming. He is currently completing a doctoral dissertation concerning Lake Bonneville stratigraphy at the University of Utah. His previous employment has been with the Antiquities Section of the Utah Division of State History and the Water Resources Division of the USGS His principal interests are in Quaternary stratigraphy and surficial deposits.

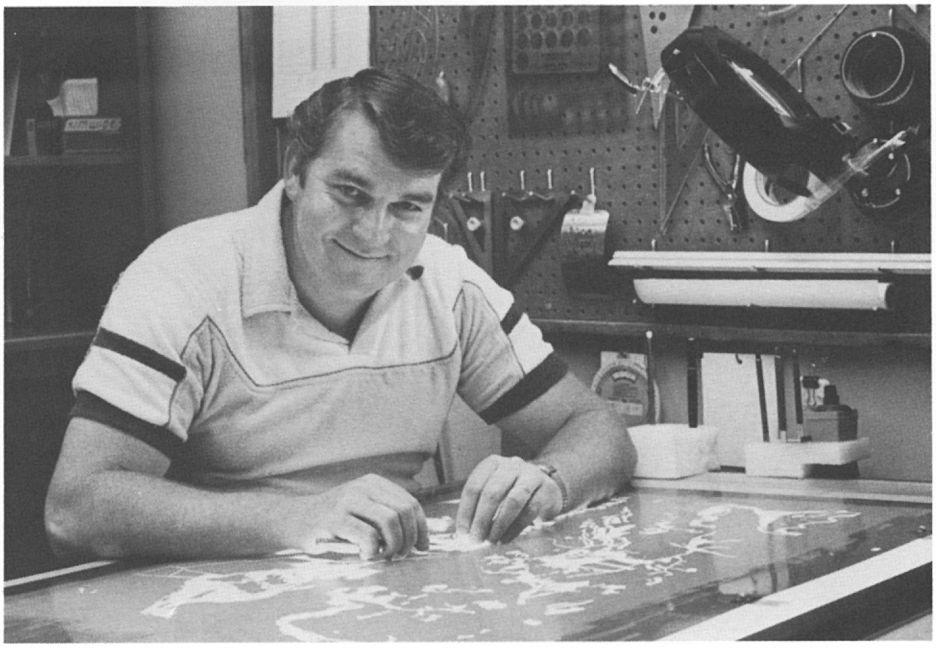
Mary Siders received both her B.A. and M.S. degree from Ohio State University (1980 and 1983). Her thesis was concerned with the study of Jurasic tholeiitic lavas in the Transantarctic Mountains and her main interests lie with volcanic rocks. She has also worked for Getty Mining Company as an exploration geologist in Utah. In addition, Mary has had mapping experience in central Utah.

Grant Willis received his B.S. degree from Brigham Young University in 1981 and will receive his M.S. from the same institution this fall. His thesis work involved the mapping of a 7½-minute quadrangle in the Sego coal field of east-central Utah. Grant also has had experience working with the USGS, Branch of Exploration Research, in the Brooks Range of northern Alaska.

Replacing **Brent R. Jones** in the editorial/illustrations section is **Dale Broadhurst**. Dale earned a B.S. degree in 1975 in geography and geology from Weber State College. Following graduate studies in geography at the University of Utah, he went on to receive his M.A. degree in education from Ohio Weslyan University. His previous employment has been with several state

(see page 16)

Brent R. Jones Leaves UGMS



R. Ollins, DNR Public Affairs

After seventeen years of dedicated service with the Utah Geological and Mineral Survey, Brent R. Jones transferred from his Survey position, July 1, 1983, to commence a new career with Department of Natural Resources's Automated Geographic Reference section.

Brent came to the UGMS from the Salt Lake City Board of Education in July 1969 where he had been employed as a junior architect. He became the first full-time geologic illustrator of the Survey. Then, the illustrations department was located in the basement at the south end of the Mines Building on the University of Utah campus. Space there was shared with the UGMS sample library, with the illustrations staff having the lesser but equally dusty space.

Brent's artistic talent was quickly recognized by the Survey's second director, Dr. William P. Hewitt, and he served for fifteen years as supervisor of the illustrations department, including two years as senior illustrator. Brent was an earlier practioner of the scribing method in professional map making. Numerous wall maps, many published in multi-color, and illustrations appearing in UGMS publications were produced with great cartographic skill by Brent.

His new assignment as a processor with AGR is a logical extension of the work he performed at UGMS. We wish Brent success and the very best in his new endeavor. ■

("Wet-Period" cont'd. from page 12)

landslides. The Office of State Planning and Budget is also involved in flying the ENVIROPOD over disaster-affected areas in Utah.

Hand-held cameras were used by the UGMS, U.S. Geological Survey, and the Department of Public Safety to photograph hazards. Utah Highway Patrol aircraft and pilots were made available to geologists of the USGS and UGMS for the study. In addition, individual citizens have made copies of photos which document events available to the UGMS. Anthony Frankovich, a professional aerial photographer, also volunteered the use of his airplane for Thistle landslide studies. The UGMS is compiling on-site, ground level photographs to fully document the 'wet-period' events.

The news media have obtained excellent documentation of some of the major geologic events this spring. Some of the video coverage obtained from helicopters by local television stations before, during, and after major disasters provides an outstanding record of important parts of these events.

The vast amount of data documenting extent, location, and occurrence of geologic hazards initiated by the recent 'wet-year' period entails an ambitious long-term program to record and study unique geologic events. ■

("Staff Changes" cont'd. from page 15)

and federal government agencies in the areas of cartography and civil engineering. Dale was chief staff cartographer for the *Atlas of Utah* (1981) and has published other map creations in various publications.

Sue Ann Finch, administrative assistant, has transferred to the Utah Travel Council. ■

("Remote Sensing" cont'd. from page 12)

volume of discharge. The gage consisted of a line across the creek with two vertical hanging lines, with a galvanized tube at water level, red flag at 2 feet, blue flag at 4 feet, orange flag at 6 feet, and additional orange flags at one-foot invervals.

Requisite equipment for observers included radio and spare battery pack, strong beam light and spare batteries, logbook with instruction page, and adverse weather gear. On arrival at the station, observers were told first to familiarize themselves with the upslope escape route path and then to immediately observe the wind conditions and water level with respect to the line gage. Because the channel walls were near vertical following the initial surge, they were cautioned to use care in approaching the channel and were asked to look for ground cracks developing in the channel vicinity. ■

GREAT SALT LAKE LEVEL

Date (1983)	Boat Harbor South Arm (in feet)	Saline North Arm (in feet)
May 1	4203.70	4200.95
May 15	4203.90	4201.20
June 1	4204.30	4201.35
June 15	4204.75	4201.55
July 1	4205.00	4201.55
July 15	4204.90	4201.65

The July 1, 1983 high at the south arm is the highest that the Great Salt Lake has been since June 1924 when it reached an elevation of 4205.1 feet. The next preceeding date when the lake elevation was at or above elevation 4205 feet was during August 1888 when the lake elevation was 4205.2 feet.

UTAH GEOLOGICAL AND MINERAL SURVEY
Survey Notes

State of Utah .... Scott M. Matheson, *Governor*
Department of Natural Resources .... Temple A. Reynolds, *Executive Director*
Utah Geological and Mineral Survey .... Genevieve Atwood, *Director*
Editor .... Klaus D. Gurgel
Editorial Staff .... Nancy A. Close, L. Angeloff Sapienza
Senior Cartographer .... Dale R. Broadhurst
Cartographers .... James W. Parker, Kent D. Brown, Jessie S. Roy

UTAH NATURAL RESOURCES
Utah Geological and Mineral Survey
606 Black Hawk Way
Salt Lake City, UT 84108-1280

Address correction requested

Bulk Rate
U.S. Postage Paid
S.L.C., Utah
Permit No. 4728

Account No. 016103
Approval No. 810047